

HOW IT WORKS

Projectors

You may still associate projectors with those relics from school days or boring holiday slideshows, but the technology has come a long way. Tom Royal huddles in a dark room and marvels at the glorious mechanics that make projectors possible

Most of us use an LCD or CRT monitor for everyday work, but if you're giving a presentation to a room full of people there's no substitute for a projector. Similarly, projectors are a great way to watch films on a big screen without having to share the experience with the feral children who inhabit the UK's multiplex cinemas. This month, we'll explain how they work.

Some older projectors were built using CRT technology. These split the full-colour image to be displayed into three colour channels – red, green and blue – which were sent to three separate cathode ray tubes. Each worked in the same way as the cathode ray tube in a monitor or television, except they displayed a single colour only. A lens mounted on the front focused the image on to a distant screen.

CRT projectors have their advantages. Black areas of the image appear black, whereas some other technologies produce only a dark grey. This is similar to the difference between CRT televisions, which produce impressive black areas, and LCD models, which can suffer from too much brightness. However, with three CRT units inside, these projectors are large, heavy and expensive. Today they exist only for specialised applications such as simulators, but you may find an old one mounted on the ceiling of a pub.

These unusual CRT-based models aside, most projectors work in a similar manner. A bright

light source is focused by a series of lenses. A mechanism is placed in the path of the light before it exits the projector. This mechanism blocks some of the light, so the corresponding areas on the screen appear dark. The three common types of projector use different technologies to block the light and produce a colour image on the screen.

CRYSTAL MAZE

The simplest type of projector uses LCD technology. It's easy to imagine how this might work: shrink the type of LCD panel used in a monitor down to a smaller size, then shine a bright light through it. In fact, there are numerous websites that document attempts to turn an old LCD display and an old-fashioned overhead projector into a colour video projector. Proper LCD projectors, however, use three separate LCD panels and three beams of light to build up a colour image.

Inside an LCD projector the light from a bulb is focused by lenses before passing through two dichroic mirrors. These reflect light of a particular wavelength, allowing the rest to pass through. Using two mirrors in series, light can be split into the three primary colours. The first mirror reflects one colour, the second another and the third passes through unobstructed.

Each colour beam then passes through an LCD panel. Like the panels used in a digital

watch, these contain several elements that can be turned black using an electrical voltage. The elements are arranged in a grid with the same resolution as the projector's output. If the unit projects an image with a resolution of 800x600 pixels, for example, each LCD will contain a grid of 800x600 elements.

When your computer sends a frame of video to the projector, electronics inside split the frame into three colour channels: red, green and blue. This produces three monochrome pictures that, if combined using red, green and blue light, produce the complete colour image. These three images are displayed on the three monochrome LCDs inside the projector, with the red channel image sent to the screen in the beam of red light, and so on. The three beams of light, now displaying three colour images, pass into a dichroic prism. This recombines the three beams into one full-colour beam of light, which passes through a final set of lenses and out of the projector. The final lenses allow you to focus the image at the size you want without moving the projector nearer to or away from the screen.

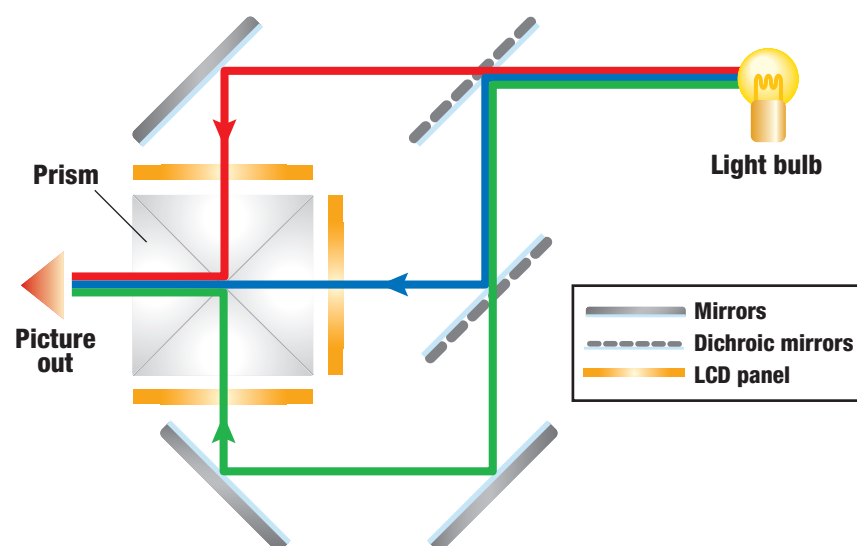
This kind of LCD projector is common. The technology can be adapted according to the area in which it is likely to be used. Office projectors have a 4:3 aspect-ratio native resolution (usually 800x600 or 1,024x768 pixels) and a powerful light source that enables them to produce a vivid image in brightly lit offices. Projectors designed for use in a home cinema will be used in the dark, so they can have a less powerful light, but most have a high-detail, widescreen resolution. Many expensive home cinema projectors can produce a 720p (1,280x720) image suitable for displaying high-definition videos, and some support the higher 1,080p standard.

PRISM BREAK

LCD projectors have a few disadvantages. With two mirrors, three screens and a prism inside, it's not possible to make a portable LCD projector. Some users also notice the so-called 'screen door' effect, where individual pixels are visible in the finished image, although this occurs in other projectors, too. More importantly, LCD projection systems have suffered from low contrast. This is because the LCD screens inside the projector have difficulty blocking out all the light from the bulb. Even with all the cells on all three screens set to black, some projectors display a dark grey screen rather than a black one.

Many pricier LCD projectors use extra technology to increase the level of contrast you get. The most common technology is called dynamic iris control. This uses a mechanism that limits the amount of light sent from the bulb into the rest of the projection mechanism.

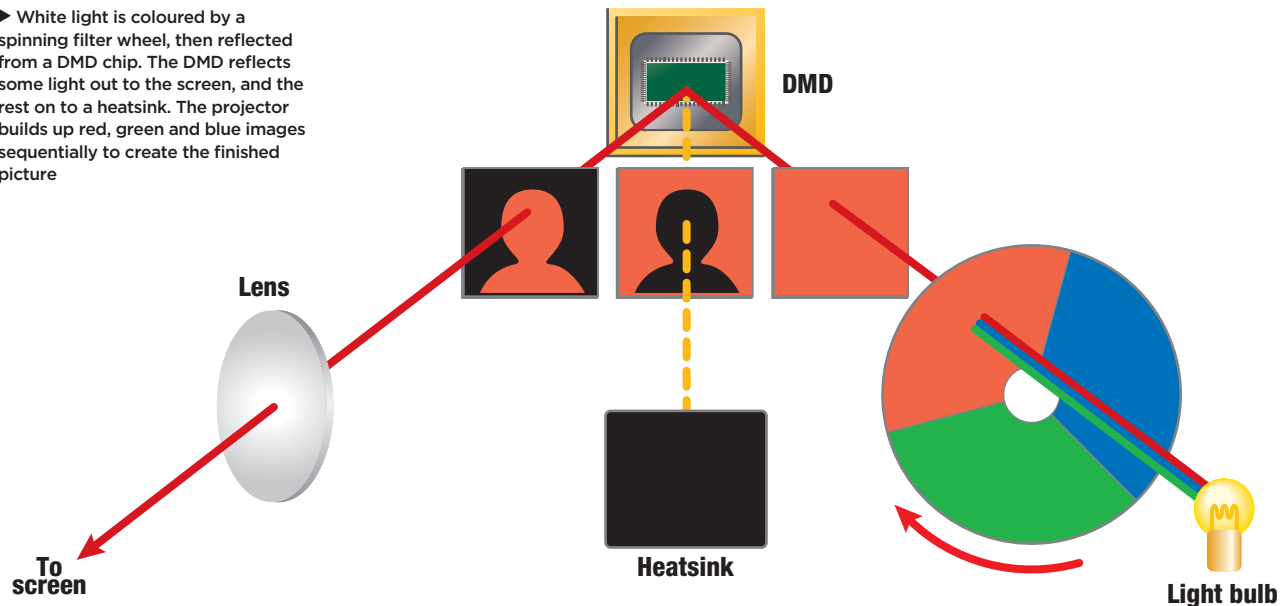
Doing the splits How LCD projectors work



▲ An LCD projector uses two dichroic mirrors to split white light into three primary colours. Each colour passes through an LCD panel before the three beams are recombined into the finished picture

Wheely good How DLP projectors work

► White light is coloured by a spinning filter wheel, then reflected from a DMD chip. The DMD reflects some light out to the screen, and the rest on to a heatsink. The projector builds up red, green and blue images sequentially to create the finished picture



In dark scenes, this iris closes up, letting through less light and producing a darker picture. The mechanism is controlled electronically and updates rapidly: Panasonic's PT-AX100U projector analyses the image and updates its iris 60 times per second.

MIRROR BALL

The most common alternative to LCD technology is digital light processing (DLP). DLP is a trademark of Texas Instruments and the term is used in the marketing of these projectors, but DLP technology is based on the generic digital micro-mirror device (DMD). The DMD, invented in the late 1980s by Dr Larry Hornbeck, is a microchip covered with thousands of tiny mirrors. It has applications outside projection systems, and the first product to use DMD was a specialised laser printer designed for printing air travel tickets.

At the heart of a DLP projector is a DMD chip with its array of tiny mirrors. Just as the LCDs in an LCD projector use an individual cell for each pixel of the image displayed, the DMD chip has a mirror for each pixel. The DMD in a projector with a native resolution of 800x600 pixels will have 480,800 tiny mirrors. Each mirror can be electronically deflected by a few degrees between two positions, which we'll call on and off. The deflection is produced by a small electrostatic charge originating from a memory cell in the chip below. Light from the projector's lamp is focused on to the DMD and its mirrors.

In the on position the mirrors reflect the light from the lamp into a set of lenses that focus it out of the projector and on to the distant screen. In the off position they reflect it on to a heatsink inside the projector's case instead. When all the mirrors are in the on position, all the light is reflected out through the lenses, producing a white display. With all the mirrors in the off position, no light leaves the projector, resulting in a black screen. By flipping some mirrors on and some off, a simple black and white image appears. The orientation of the mirrors can be changed many times per second, though, so the DMD can exploit the threshold at which the

human eye perceives flicker. By leaving the mirrors on most of the time but occasionally turning them off, the human eye perceives a light grey shade. By turning the mirrors off more of the time, a darker grey is perceived. This allows the DMD to produce greyscale images.

There are two ways of using this technology to produce a colour image. The simplest is to split white light into the three primary colours, then reflect each one from a separate DMD chip. This works perfectly well, but the DMD chips are expensive to produce, so using three of them pushes the cost of the projector up enormously. Projectors using three DMD chips are used to project films in some cinemas, but we've never seen one designed for home or office use.

Home and office projectors use a single DMD and reflect red, green and blue lights sequentially from this one chip. A wheel containing red, green and blue filters spins rapidly, passing the filters through the light. The coloured light is reflected from the DMD and out of the projector. The wheel with the coloured filters must be synchronised with the operations of the DMD to produce the correct picture. Some DLP products have no colour wheel at all and use bright red, green and blue LEDs instead, flashing them on and off as required.

Like LCD technology, DLP has obvious advantages and disadvantages. With only one chip rather than three LCDs inside, DLP projectors can be built in extremely small cases, making them ideal for business users who need a portable projector. However, displaying the three colours that make up each frame sequentially rather than simultaneously can result in a colour problem known as the 'rainbow effect'. This rainbow-coloured fringe is most visible on bright objects displayed on a dark background, such as white movie credits scrolling over black. The rainbow effect can be reduced by increasing the frequency at which the three colours alternate. Many projectors use a wheel with more than three filter segments, so for each rotation of the wheel each colour of light is shown two, three or four times. Similarly, flashing the LEDs on an LED DLP projector more rapidly reduces the visibility of rainbow fringes.

Cinema projectors that use three DMDs show all three colours simultaneously, eliminating the rainbow effect entirely.

CRYSTAL TIPS

LCD and DLP technology account for most of the home and office projector market, but there is one other technology available. Liquid crystal on silicon (LCOS) combines elements of LCD and DLP technology. Like DLP it uses a silicon chip to reflect light selectively, and like LCD it uses liquid crystal rather than mirrors to prevent light reaching areas of the screen. Annoyingly, LCOS is a trademark, so individual manufacturers use different names for versions of this technology. Sony has marketed LCOS projectors under the ridiculous semi-acronym SXRD, where X stands for the word 'Crystal' in Silicon Crystal Reflective Display. JVC calls its LCOS technology DILA.

An LCOS chip has a reflective substrate covered with LCD cells. When the cells are inactive, light passes through them and reflects from the substrate and out of the projector. When the cells are active, they block the light, so it doesn't reflect. An LCOS chip can be used with a colour wheel in much the same way as a simple DLP projector, but most of the LCOS products currently on sale split white light into the three primary colours before reflecting it from three chips and recombining the three beams into a full-colour image. At the moment, LCOS comes at a price: Canon's Xeed SX50 projector costs around £2,500. 

FURTHER INFORMATION

Detailed explanation of an LCD projector

www.3lcd.com/structure_close_up.html

DLP technology

www.dlp.com/dlp_technology/dlp_technology_overview.asp

Sony's SXRD (LCOS) technology

<http://tinyurl.com/el3rr>